Feeddowns for Run II

- Basic Idea
- Configuration for Run II
- Calibration of Feeddowns
- Settings in Run II

Basic Idea

Sextupole field $\left(K_2L\right)$ with tilt angle ψ (i.e. normal or skew) and orbit offset $\left(x_0, y_0\right)$ gives a feeddown quadrupole (or skew quadrupole) field

$$(K_1L)_{no} = K_2L\left(x_0 \cos 3\psi + y_0 \sin 3\psi\right)$$

$$\left(K_1L\right)_{sq} = K_2L\left(x_0 \sin 3\psi - y_0 \cos 3\psi\right)$$

Basic Idea

These are used to adjust the differential tunes and coupling of the proton and pbar helix

$$\Delta \nu_x = (2)\frac{1}{4\pi}\sum \beta_{\mathrm{x,\,i}} \; (\mathrm{K}_1\mathrm{L})_{\mathrm{no,\,i}}$$

$$\Delta \nu_y = -(2)\frac{1}{4\pi}\sum \beta_{y,i} \; (\mathrm{K}_1\mathrm{L})_{\mathrm{no,i}}$$

Note the sine and cosine term for the coupling

$$\Delta \mathrm{C}_{\mathrm{sq}} = (2)\frac{1}{2\pi}\sum (\mathrm{K}_1\mathrm{L})_{\mathrm{sq,i}} \sqrt{\beta_{x,i}\beta_{y,i}} \cos(\phi_{\mathrm{y}} - \phi_{\mathrm{x}})$$

$$\Delta \mathrm{S}_{\mathrm{sq}} = (2)\frac{1}{2\pi}\sum (\mathrm{K}_1\mathrm{L})_{\mathrm{sq,i}} \sqrt{\beta_{x,i}\beta_{y,i}} \sin(\phi_{\mathrm{y}} - \phi_{x})$$

$$\Delta \nu_{\mathrm{min}} = \frac{1}{2}\sqrt{\Delta \mathrm{C}_{\mathrm{sq}}^2 + \Delta \mathrm{S}_{\mathrm{sq}}^2}$$

Basic Idea

Need 4 separate (and orthogonal) circuits to control 4 lattice parameters: horizontal and vertical tune, and sine and cosine term of the coupling.

$$\begin{pmatrix} S1 \\ S2 \\ S3 \\ S6 \end{pmatrix} = \mathbf{M}_{\substack{\text{Inj.} \\ \text{Helix}}} \begin{pmatrix} \Delta\nu_x \\ \Delta\nu_y \\ \Delta C_{sq} \\ \Delta S_{sq} \end{pmatrix}$$

$$\begin{pmatrix} S4 \\ S5 \\ S1 \\ S7 \end{pmatrix} = \mathbf{M}_{\substack{\text{Coll.} \\ \text{Helix}}} \begin{pmatrix} \Delta\nu_x \\ \Delta\nu_y \\ \Delta C_{sq} \\ \Delta S_{sq} \end{pmatrix}$$

Circuit	Injection Helix	Collision Helix
S1	$\Delta\nu_x$	ΔC_{sq}
S2	$\Delta\nu_y$	
S3	ΔC_{sq}	
S4		$\Delta\nu_x$
S5		$\Delta\nu_y$
S6	ΔS_{sq}	
S7		ΔS_{sq}

Basic Idea

Choose locations for feeddowns using:

- Available space for magnets
- Consider helix separation (x_0 , y_0)
- Consider lattice functions (β_x ,β_y)
- Phase advance (ϕ_x - ϕ_y)
- "Pair up" correctors to null effect on chromaticity

This is why there are two "sets" of feedowns: injection and collision helix

Changes from Run I -> Run II

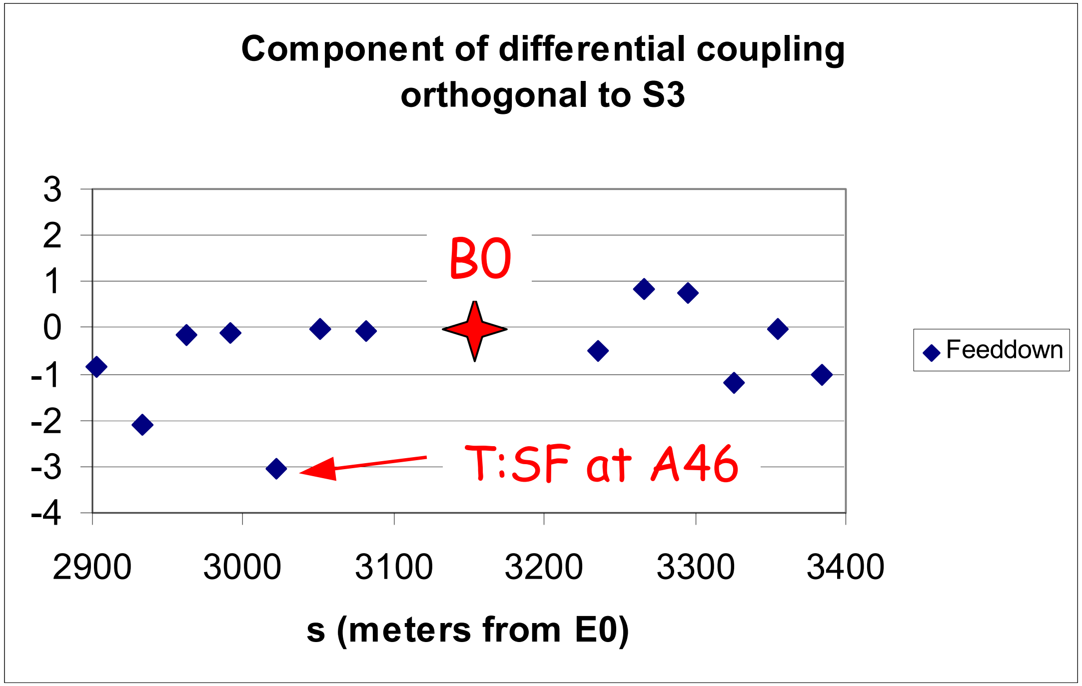
In Run I could not decouple both proton and pbar helix using the existing feeddown circuits.

Two new feeddown circuits added to improve the coupling adjustments.

The S6 (and S7) coupling circuits are orthogonal -- sort of -- to the S3 (and S1) circuits.

The horizontal and vertical betatron phase advances are roughly equal in the arcs, so S6 and S7 are located near B0 and D0.

Use a T:SF magnet for S6

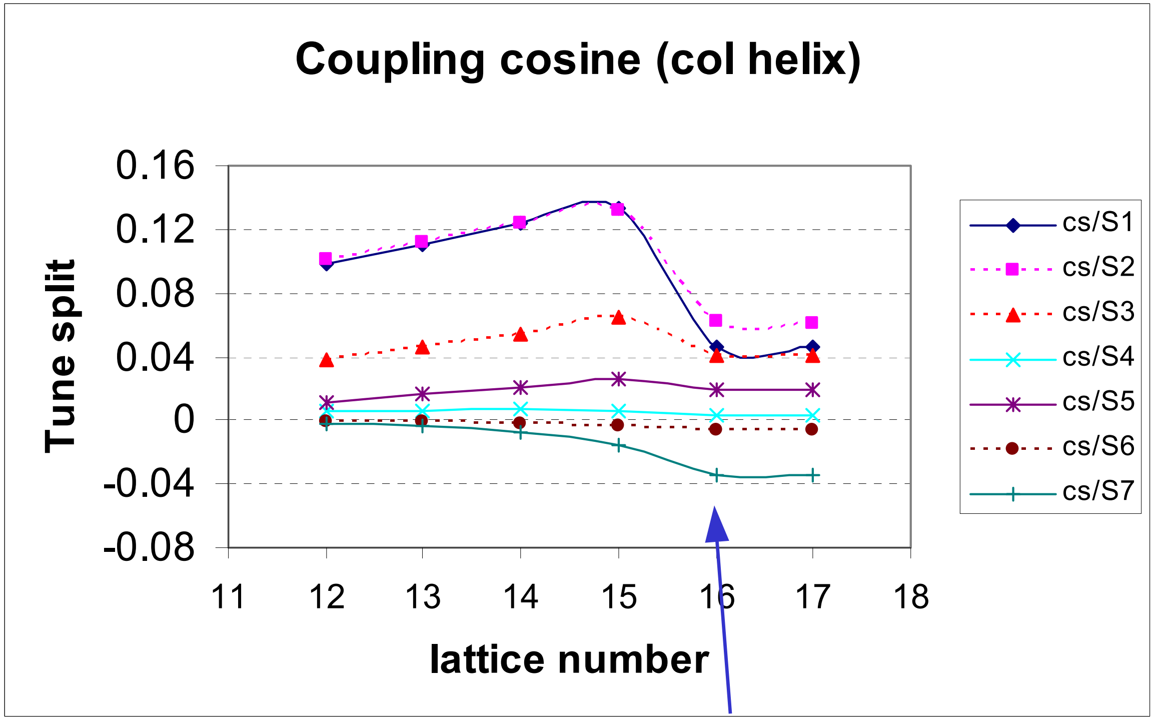


Locations of feeddowns

Circuit Name	Polarity	Magnet location	Spool type	Modified for Run II
C:S1B1A	-	B19	E	
C:S1B3A	+	B38	E	
C:S1C2A	+	C24	E	
	-	C32	G	
C:S1E2A	+	E24	E	
	-	E28	E	
C:S1F2A	+	F19	E	
	-	F26	G	
C:S1F3A	+	F34	E	
	-	F38	E	
C:S2A1A	-	A14	D	
C:S2A3A	+	A33	D	
C:S2B4A	-	B43	D	
	+	B47	D	
C:S2C3A	+	C27	D	
	-	C33	D	
C:S2D2A	-	D23	D	
	+	D27	D	
C:S2F1A	+	F12	D	
	-	F16	D	
C:S2F2A	+	F23	D	
C:S2F4A	-	F43	D	

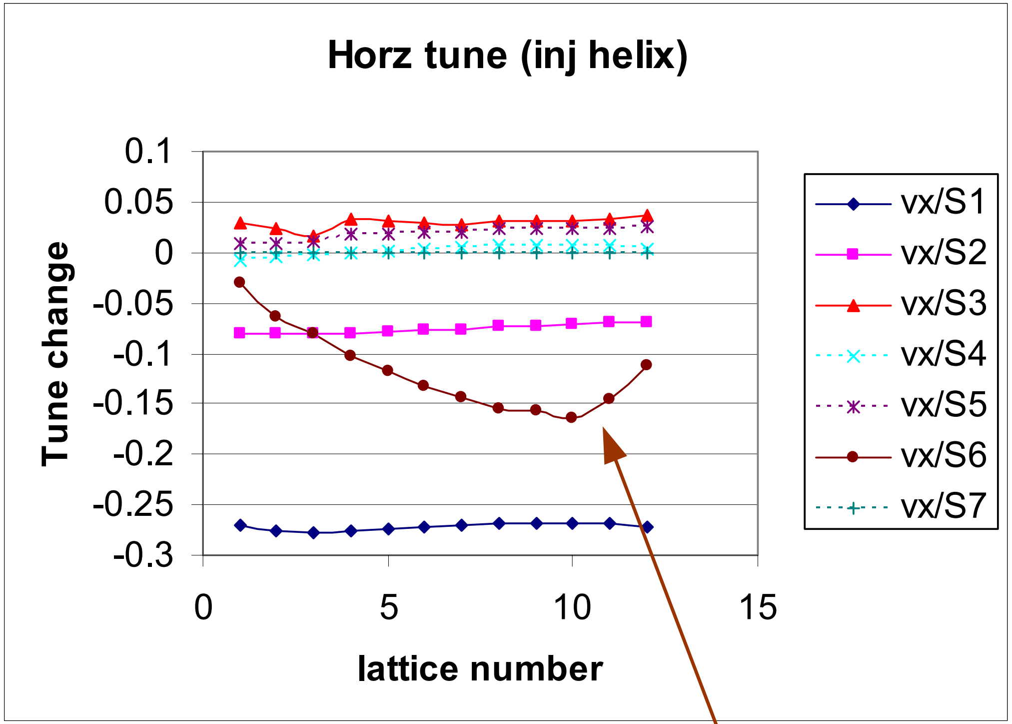
Circuit Name	Polarity	Magnet location	Spool type	Modified for Run II
C:S3A2A	+	A17	C	
	-	A24	C	
C:S3D2A	-	D19	C	
	+	D26	C	
C:S3D4A	+	D38	C	
	-	D46	C	
C:S3E1A	-	E17	C	
	+	E22	C	
C:S3E3A	-	E32	C	
	+	E36	C	
C:S4C2A	+	C19	E	
	-	C26	G	
C:S4C2B	+	C22	G	
	-	C28	E	
C:S4F2A	+	F24	E	Polarity
	-	F28	E	Polarity
C:S5A2A	+	A18	D	
C:S5A3A	-	A37	D	
C:S5D3A	-	D33	D	
	+	D37	D	
C:S5F1A	-	F14	D	
C:S5F3A	+	F33	D	
C:S6A4A	+	A46	T:SF	New
C:S6C4A	-	C46	T:SF	New
C:S7B1A	+	B14	T:SD	New
C:S7D1A	+	D14	T:SD	New

Consistency versus lattice



Phase bump is introduced

Consistency versus lattice



S6 circuit adds significant horizontal tune change

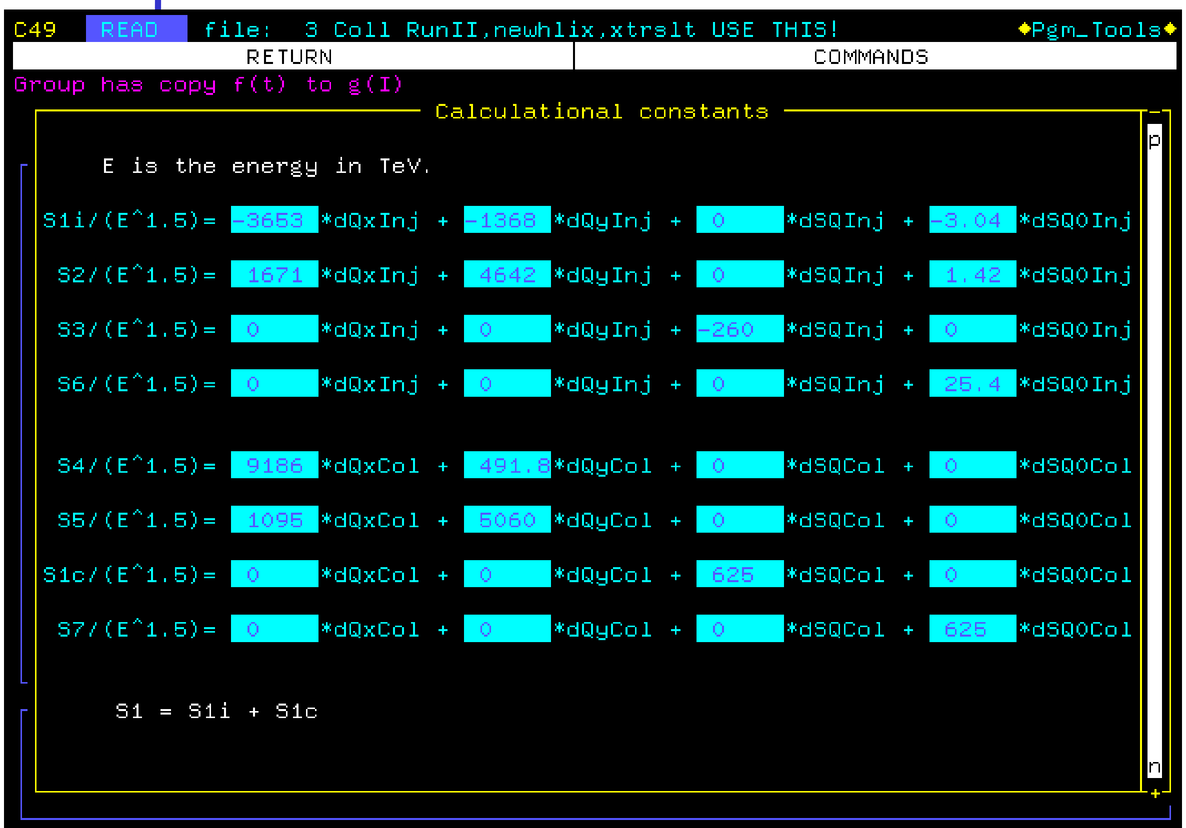
Feedown consistency

Even though feeddowns behave differently at each lattice step, still use only one set of coefficients for all lattice steps.

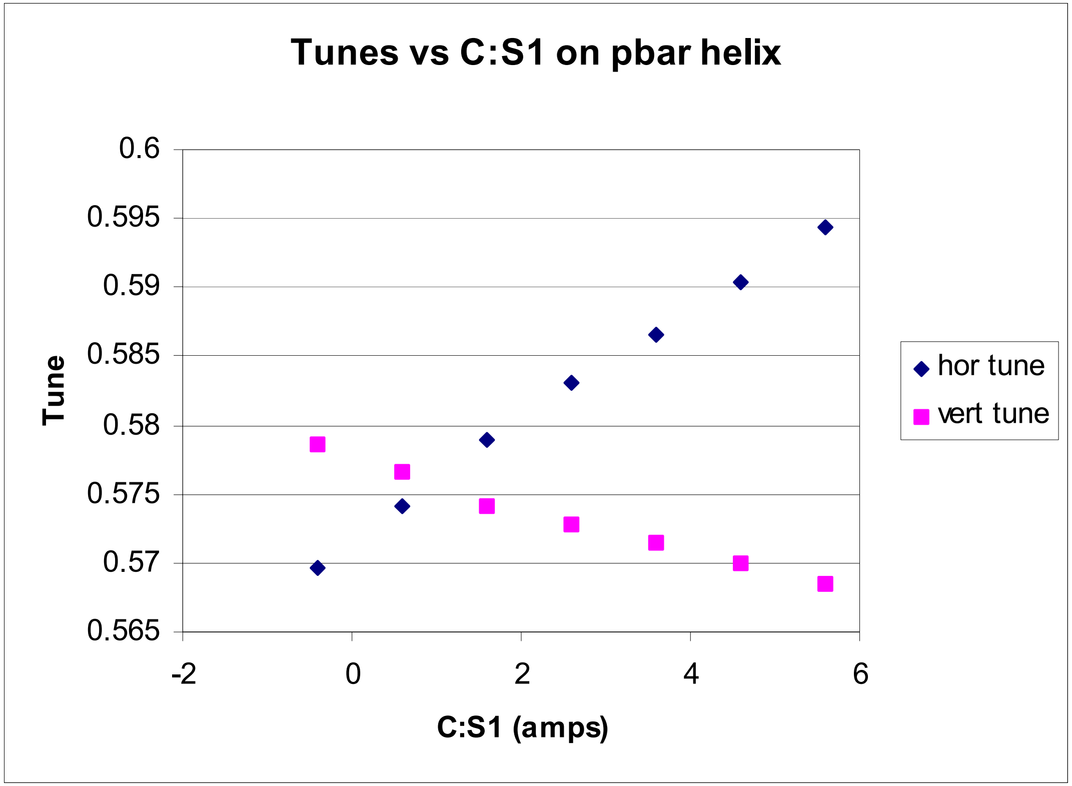
$$\begin{pmatrix} S1 \\ S2 \\ S3 \\ S6 \end{pmatrix} = \mathbf{M}_{\substack{\text{Inj.} \\ \text{Helix}}} \begin{pmatrix} \Delta\nu_x \\ \Delta\nu_y \\ \Delta C_{sq} \\ \Delta S_{sq} \end{pmatrix} \qquad \begin{pmatrix} S4 \\ S5 \\ S1 \\ S7 \end{pmatrix} = \mathbf{M}_{\substack{\text{Coll.} \\ \text{Helix}}} \begin{pmatrix} \Delta\nu_x \\ \Delta\nu_y \\ \Delta C_{sq} \\ \Delta S_{sq} \end{pmatrix}$$

Feedown consistency

Even though feeddowns behave differently at each lattice step, still use only one set of coefficients for all lattice steps.



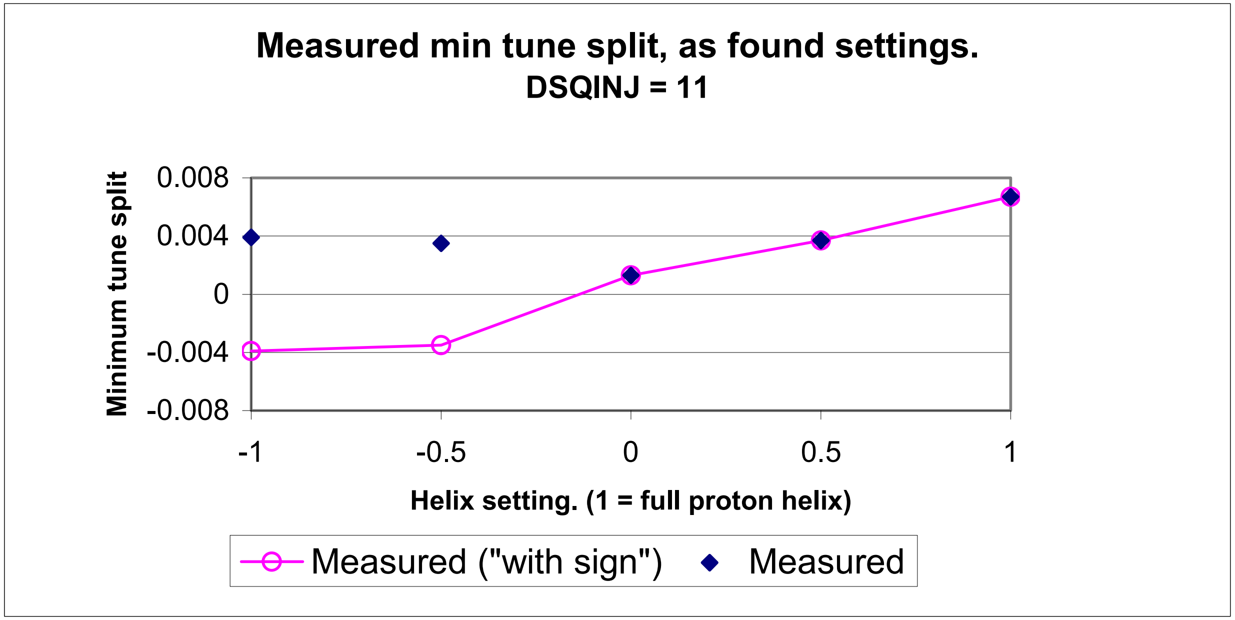
Calibration of feeddowns

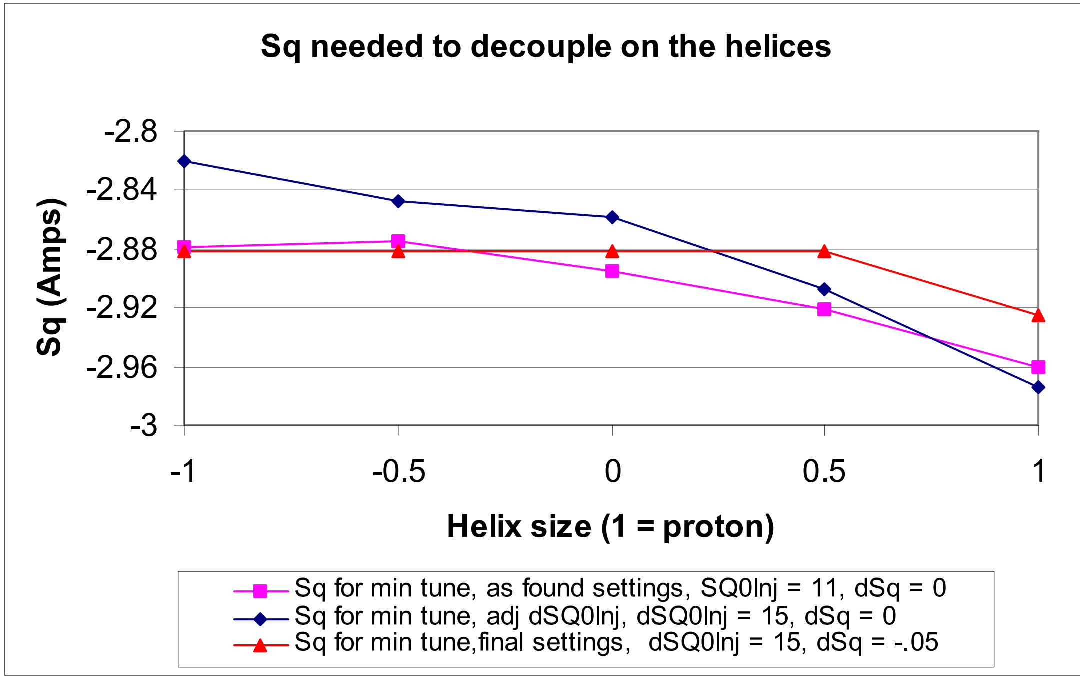


My recollection is that measured slopes agreed with calculations to ~10-15%. (Reference??)

Measurement of the tunes and coupling as a function of helix size at 150 Gev and adjustment of feeddowns.

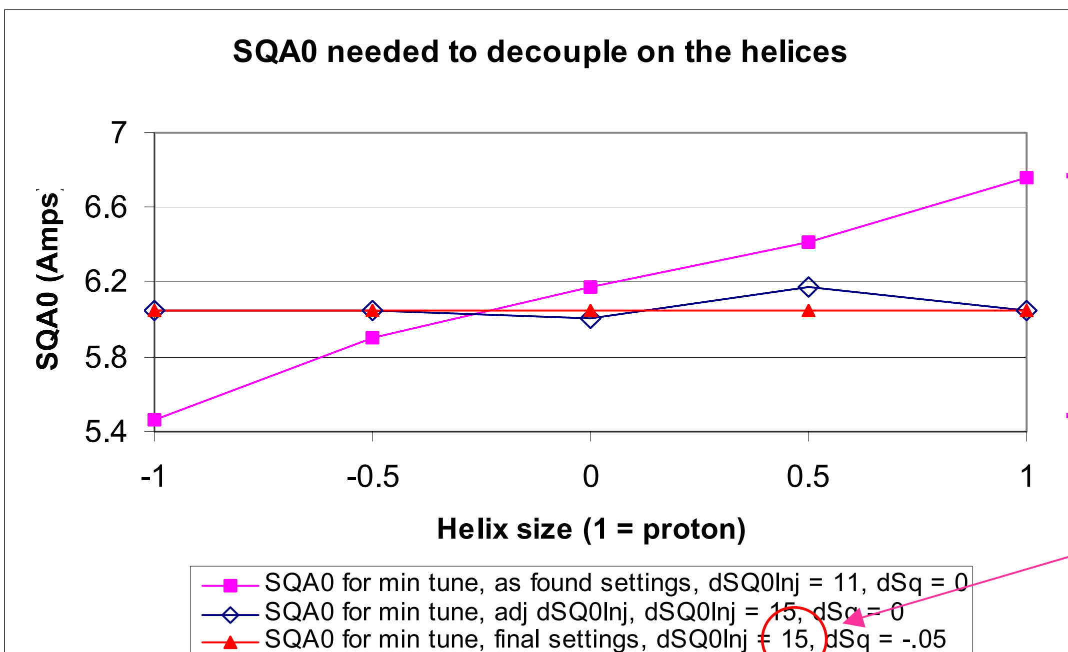
Fermilab/BD/TEV
Beams-doc-437
February 7, 2003
M. Martens, J. Annala





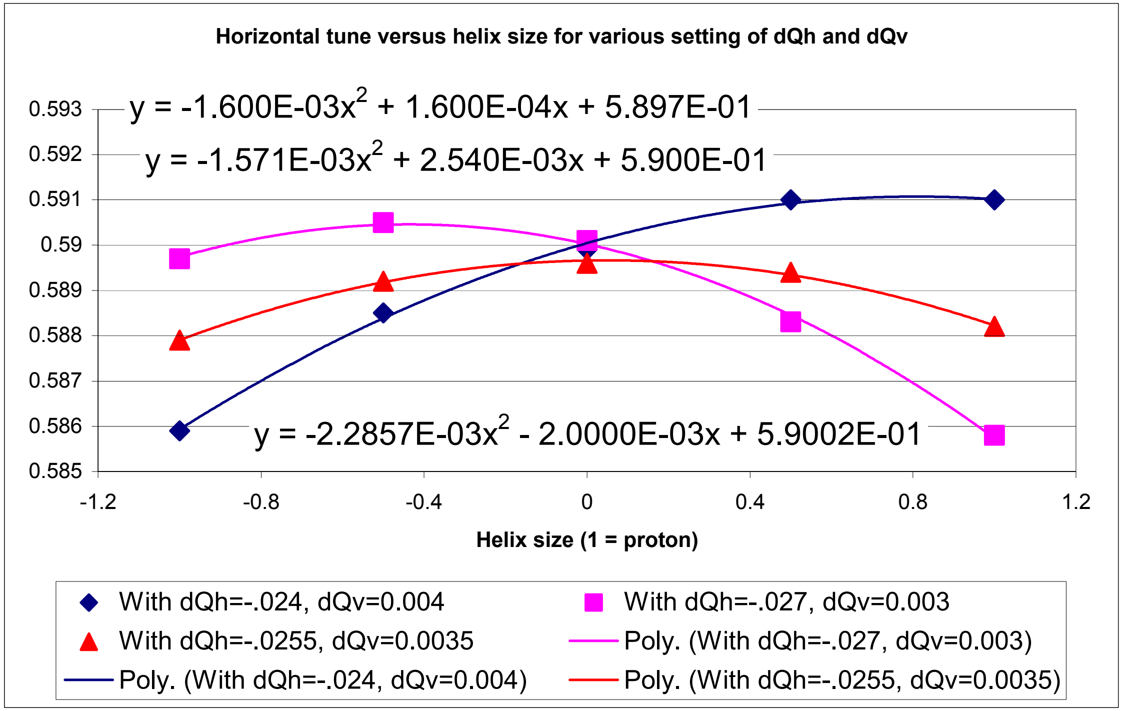
~0.008
min tune split

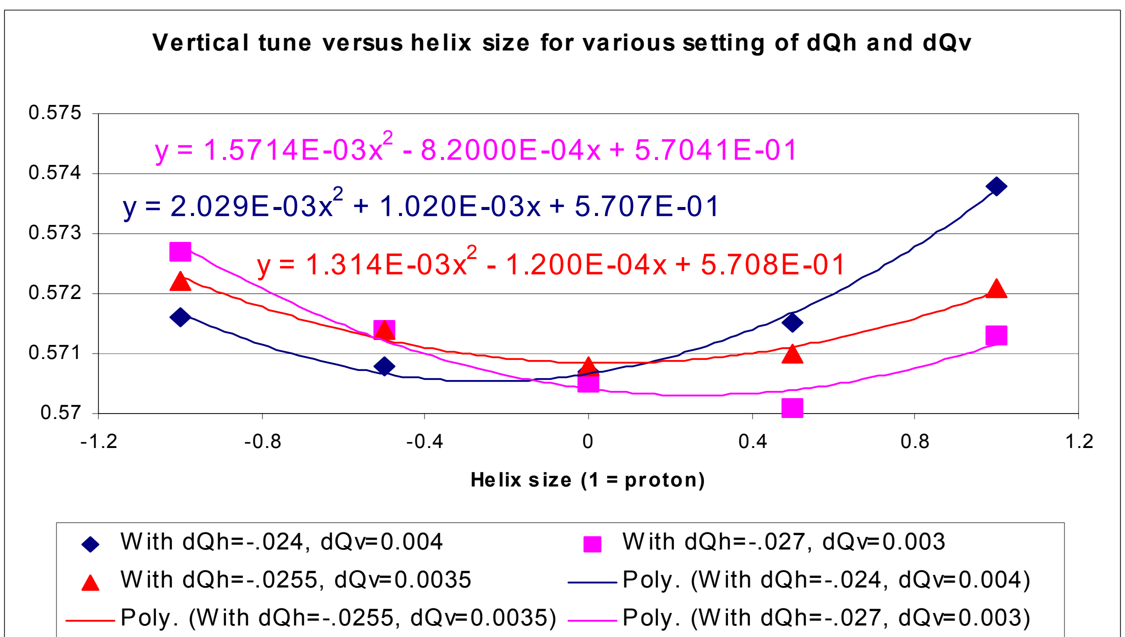
SQA0 is only 40 degrees
Orthogonal to Sq



~0.012
min tune split

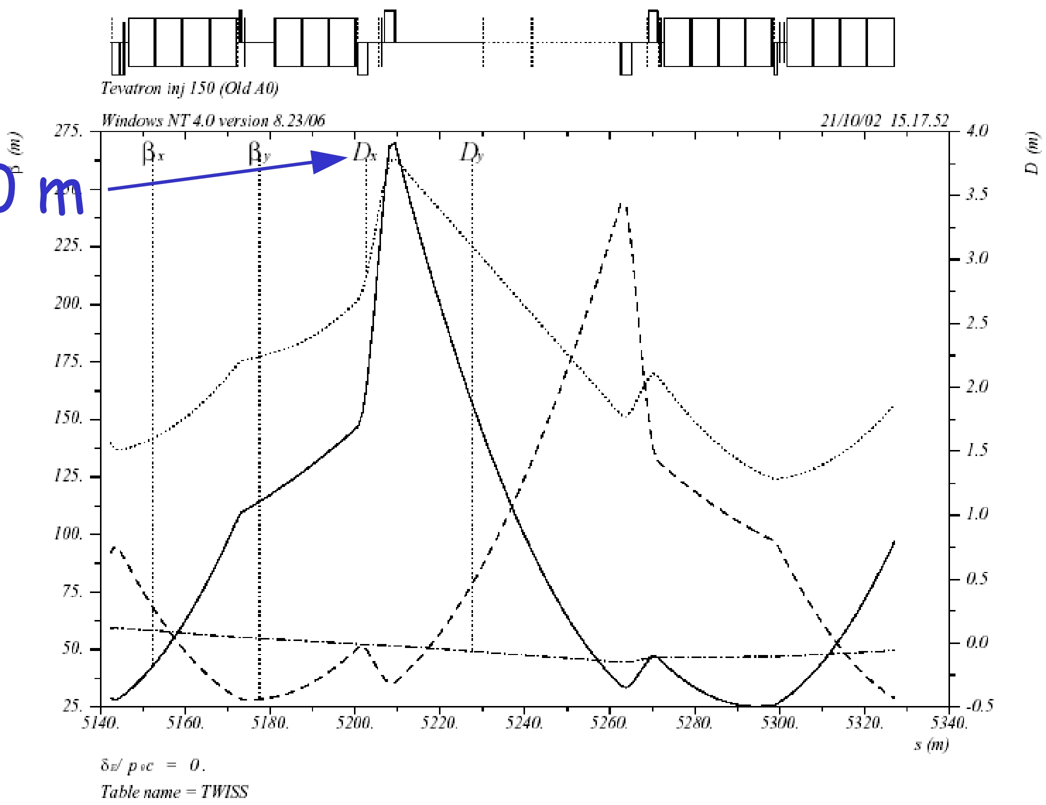
dSQ0Inj = 15 is
~20 amps on S6 circuit.


Horizontal tune versus helix size for various setting of dQh and dQv
y = -1.600E-03x2 + 1.600E-04x + 5.897E-01
y = -1.571E-03x2 + 2.540E-03x + 5.900E-01
y = -2.2857E-03x2 - 2.0000E-03x + 5.9002E-01
0.593
0.592
0.591
0.59
0.589
0.588
0.587
0.586
0.585
-1.2
-0.8
-0.4
0
0.4
0.8
1.2
Helix size (1 = proton)
With dQh=-.024, dQv=0.004
With dQh=-.027, dQv=0.003
With dQh=-.0255, dQv=0.0035
Poly. (With dQh=-.027, dQv=0.003)
Poly. (With dQh=-.024, dQv=0.004)
Poly. (With dQh=-.0255, dQv=0.0035)


Vertical tune versus helix size for various setting of dQh and dQv
y = 1.5714E-03x2 - 8.2000E-04x + 5.7041E-01
y = 2.029E-03x2 + 1.020E-03x + 5.707E-01
y = 1.314E-03x2 - 1.200E-04x + 5.708E-01
0.575
0.574
0.573
0.572
0.571
0.57
-1.2
-0.8
-0.4
0
0.4
0.8
1.2
Helix size (1 = proton)
With dQh=-.024, dQv=0.004
With dQh=-.027, dQv=0.003
With dQh=-.0255, dQv=0.0035
Poly. (With dQh=-.024, dQv=0.004)
Poly. (With dQh=-.0255, dQv=0.0035)
Poly. (With dQh=-.027, dQv=0.003)

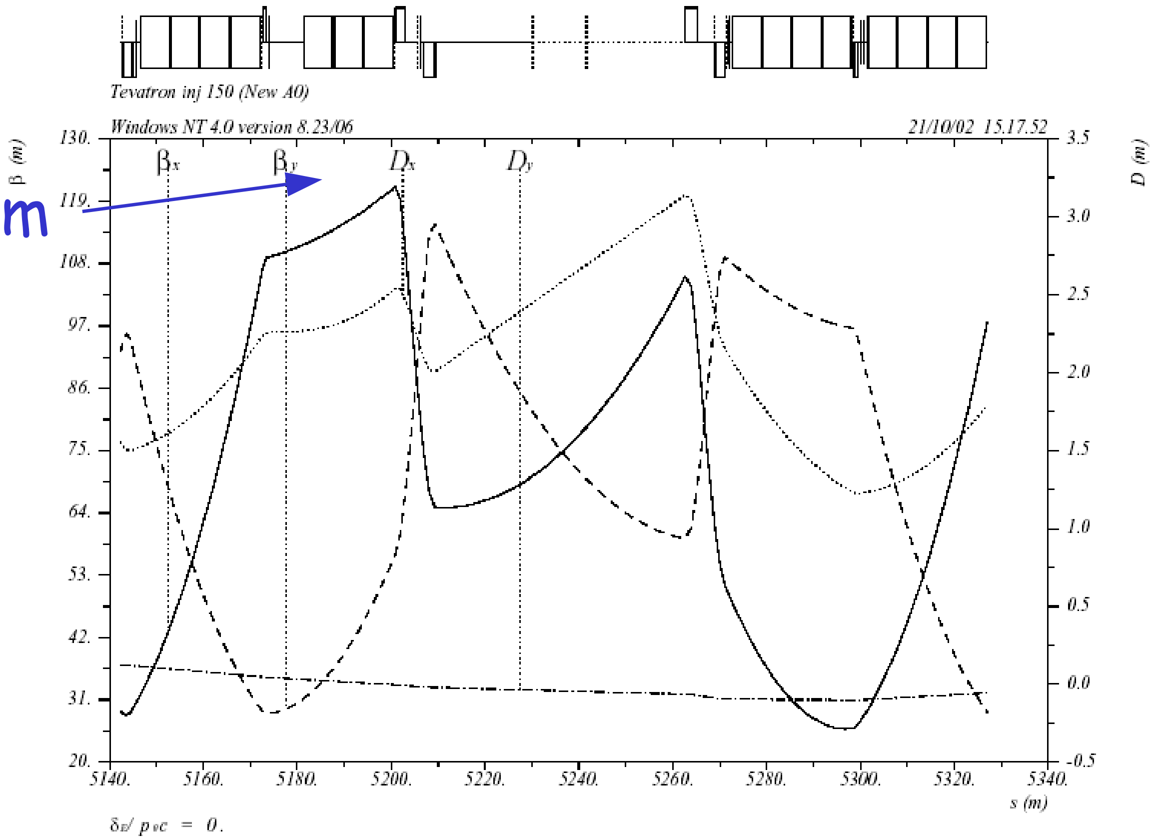
A0 Lattice

β= ~250 m

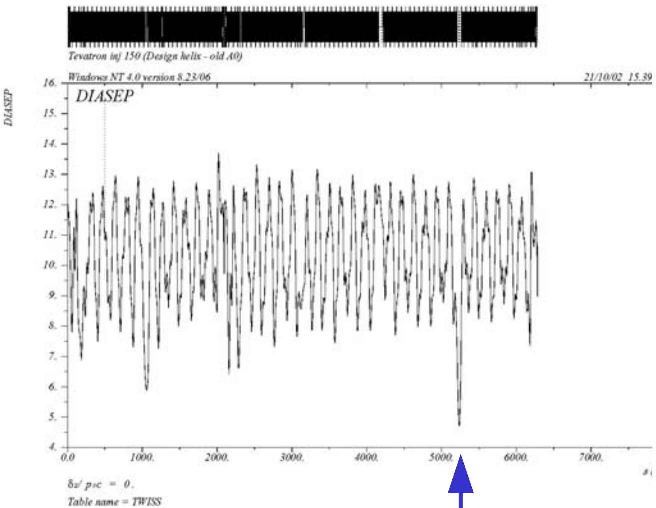


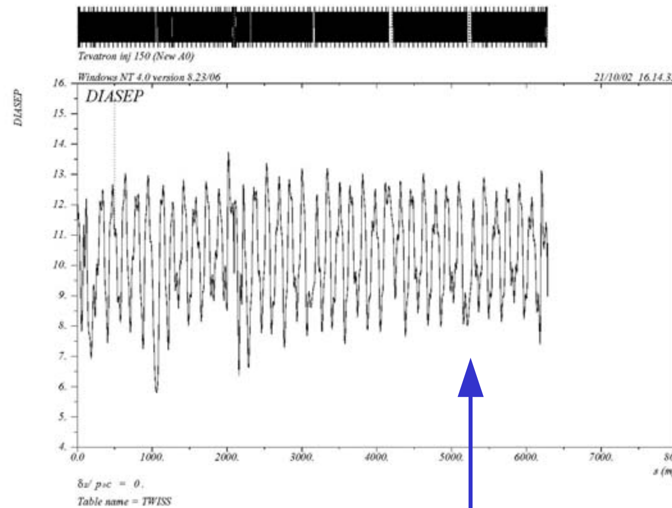
A0 Lattice modification

β= ~120 m



Increase sigma separation





Old A0 lattice:
Separation is 4.6 σ

Proposed A0 lattice:
Separation is ~8σ

These calculations do not include
width due to momentum spread.

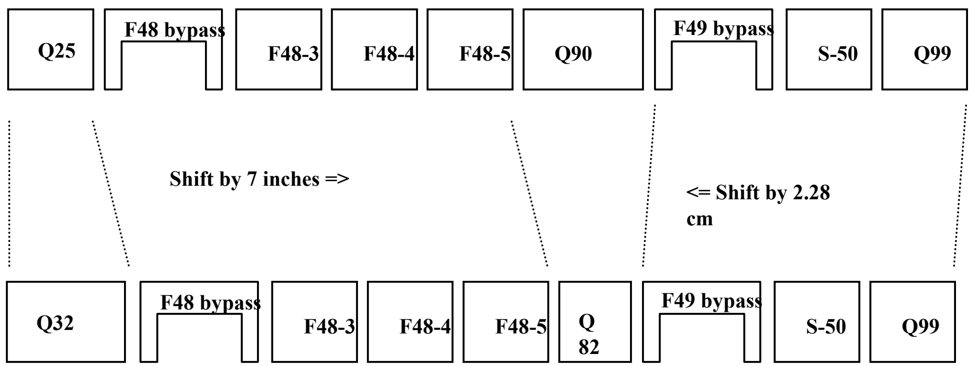


Figure Suggested modification to the F4 section of the Tevatron for the solution which uses the existing cryogenic bypasses. This solution involves moving the three dipoles at F48

Replace A0 with an E0 like lattice

- The 25 inch quadrupoles at F48 and A12 are replaced by 32 inch quadrupoles.
- The 90 inch quadrupoles at F49 and A11 are replaced with 82 inch quadrupoles
- The 99 inch quads at the two ends of the A0 straight section are reversed in order to effectively switch their polarity.
- The 3 dipoles at F49 and the 4 dipoles at A11 are also moved closer together with each set of magnets moved by about 5-7 inches.
- The A0 straight section being moved radial outward by about **5 mm???**
- Requires construction of new cryogenic bypasses.
- Time consuming for the F48 bypass
  - It is a special bypass with taps into the cyrogenics for the Tevatron Electron Lense and the superconductor in this bypass is captured by ceramic pieces.
  - A quick estimate is six months for the construction of such a bypass.

Keep F48 and A11 dipoles fixed

- The dipoles at F48 and A11 are left in place.
- The Tevatron centerline in the A0 warm straight section remains fixed.
- Requires shortening the F48 bypass by about 7 inches.
- Requires a 7 inch cryo extension at F49
- Requires shortening the bypass at A11.
- The main problem with this solution is replacing the 25 inch quad at A12 with a 32 inch quad.
  - There are no straight sections to shorten.
  - Therefore requires a modification to the cryogenic lattice.
  - Replace a 72 inch long spool piece at A12 with a shorter one?

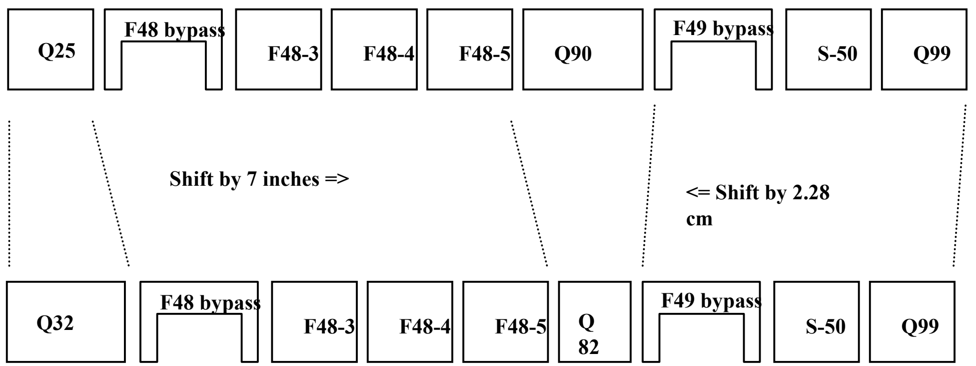


Figure Suggested modification to the F4 section of the Tevatron for the solution which uses the existing cryogenic bypasses. This solution involves moving the three dipoles at F48

Use existing cyro bypasses

- Construction of cryogenic bypasses is a long lead time task (~six months)
- So use existing bypasses and shift the dipoles and quadrupoles.
- On the F4 side, the 25 inch quadrupole is replaced by a 32 inch quadrupole. The F48 bypass and the three F48 dipoles are all shifted closer to A0 by 7 inches. The 90 inch quadrupole at F49 is replaced by a 82 inch quadrupole. This leaves a 2.28 cm gap between the downstream end of the 82 inch quad and the F49 bypass. To compensate for this it will probably be easiest to shift the F49 bypass, the F49 spool piece, and the 99 inch quadrupole further away from A0 by 2.28 cm.
- On the A1 side, the 72 inch spool piece is replaced by a shorter spool piece. The 25 inch quadrupole at A12 is replaced by a 32 inch quadrupole. The four dipoles at A11 and the A11 spool piece are then shifted by 0.1253 meters. This keeps the orbit closed at A0. The 90 inch quadrupole at A11 is replaced by an 82 inch quadrupole. This leaves a gap of 6.43 cm between the quadrupole and the A11 bypass. It will probably be easiest to shift the 99 inch quadrupole and A11 bypass away from A0 by 6.43 cm. There will also need to be a cryo extension at A12 to compensate for the shorter spool piece.

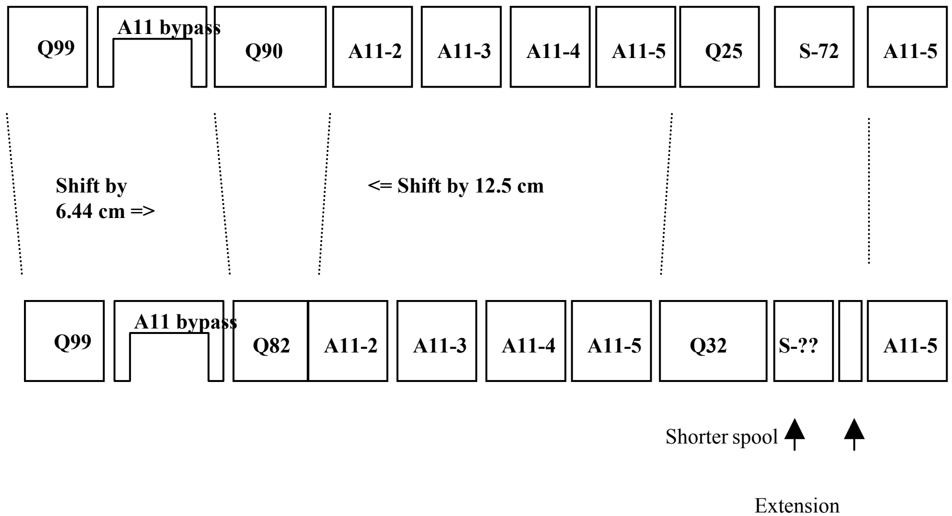


Figure Suggested modification to the FA11 section of the Tevatron for the solution which uses the existing cryogenic bypasses. This solution involves moving the three dipoles at F48